

X-ray Reflection Gratings: Shaping, Metrology, Assembly

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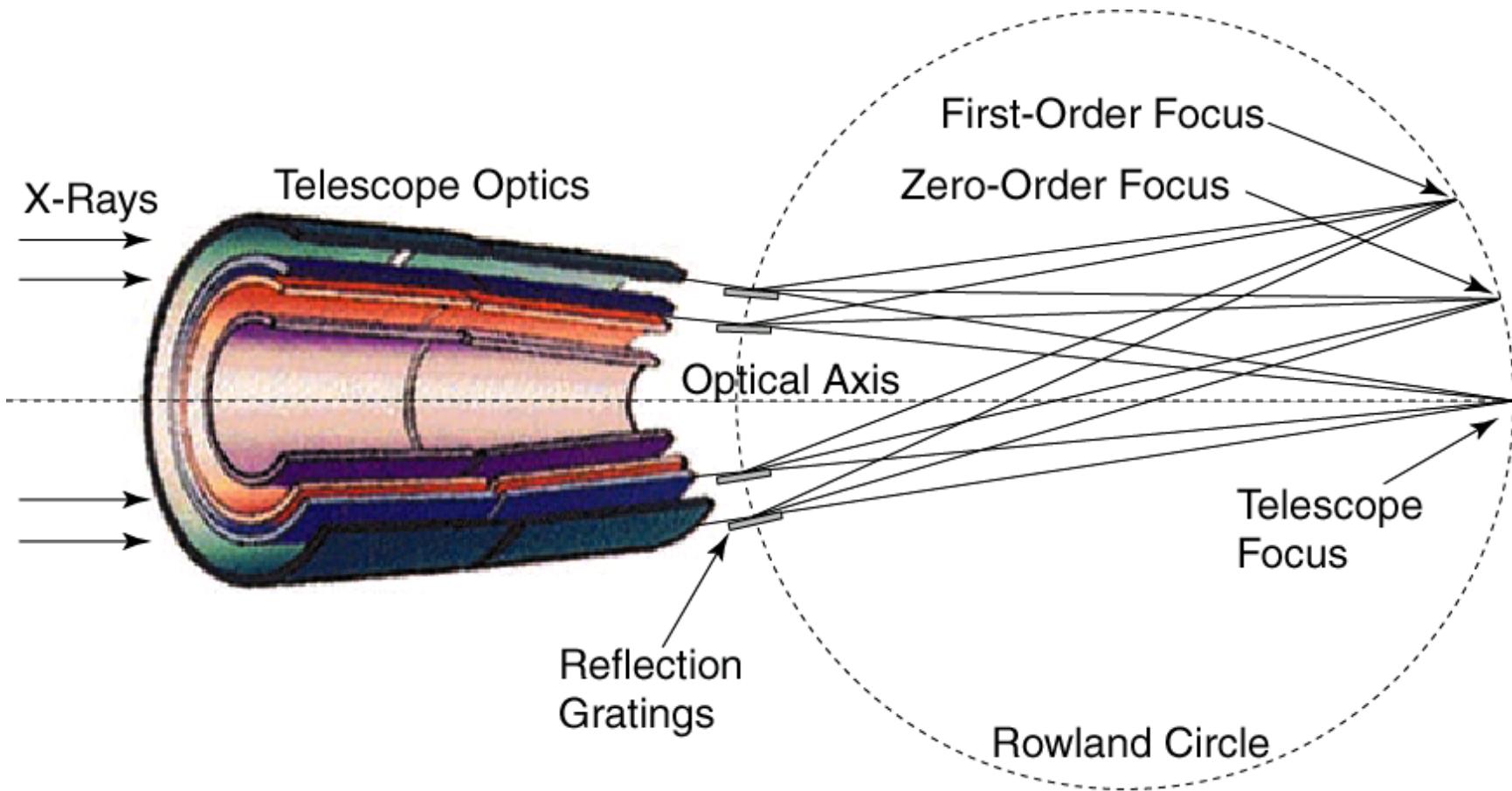


Outline

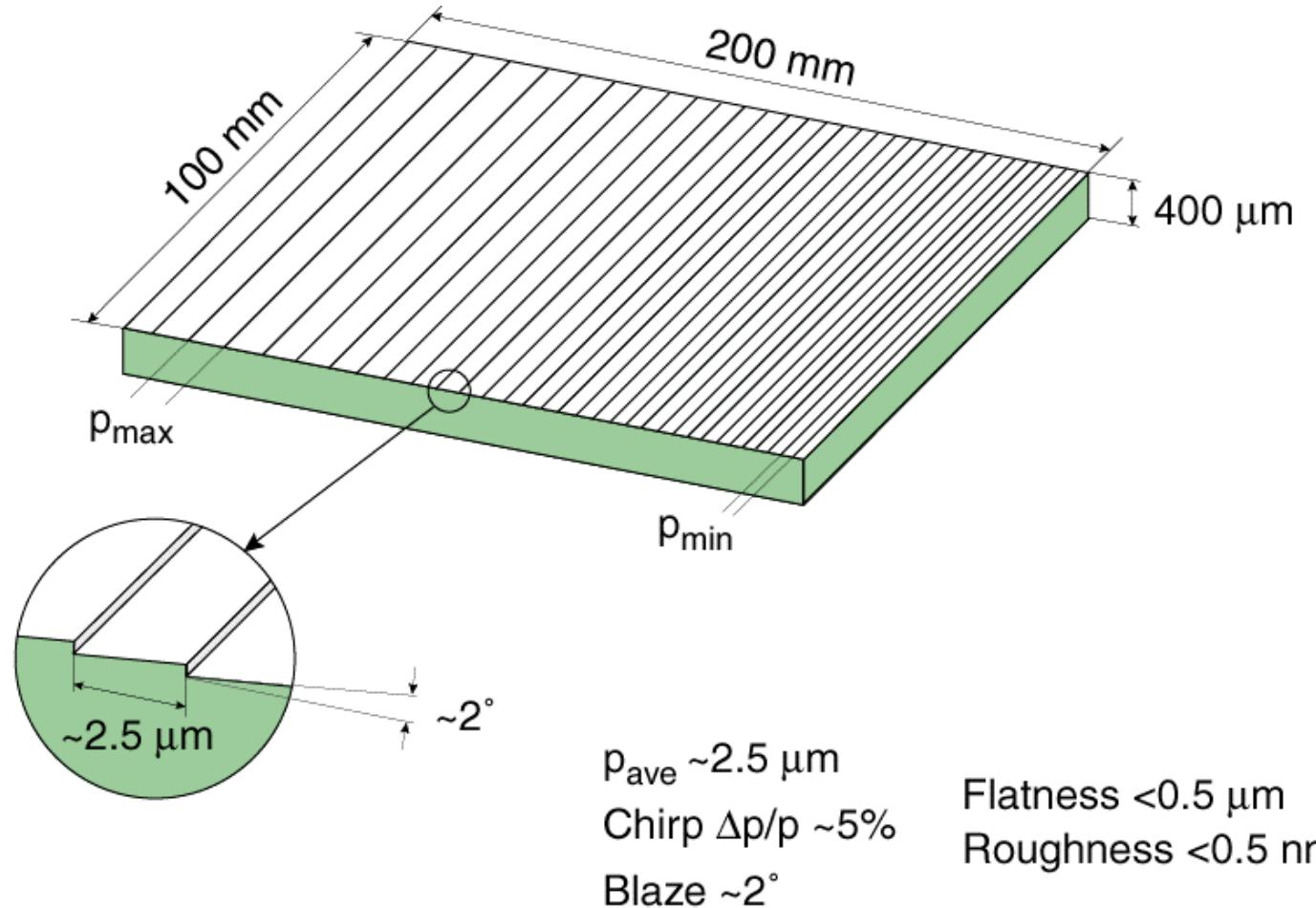
- Grating implementation and design
- Shaping
 - Magneto-rheologic fluid polishing (MRF)
- Surface metrology
 - Shack-Hartmann system
- Assembly Truss



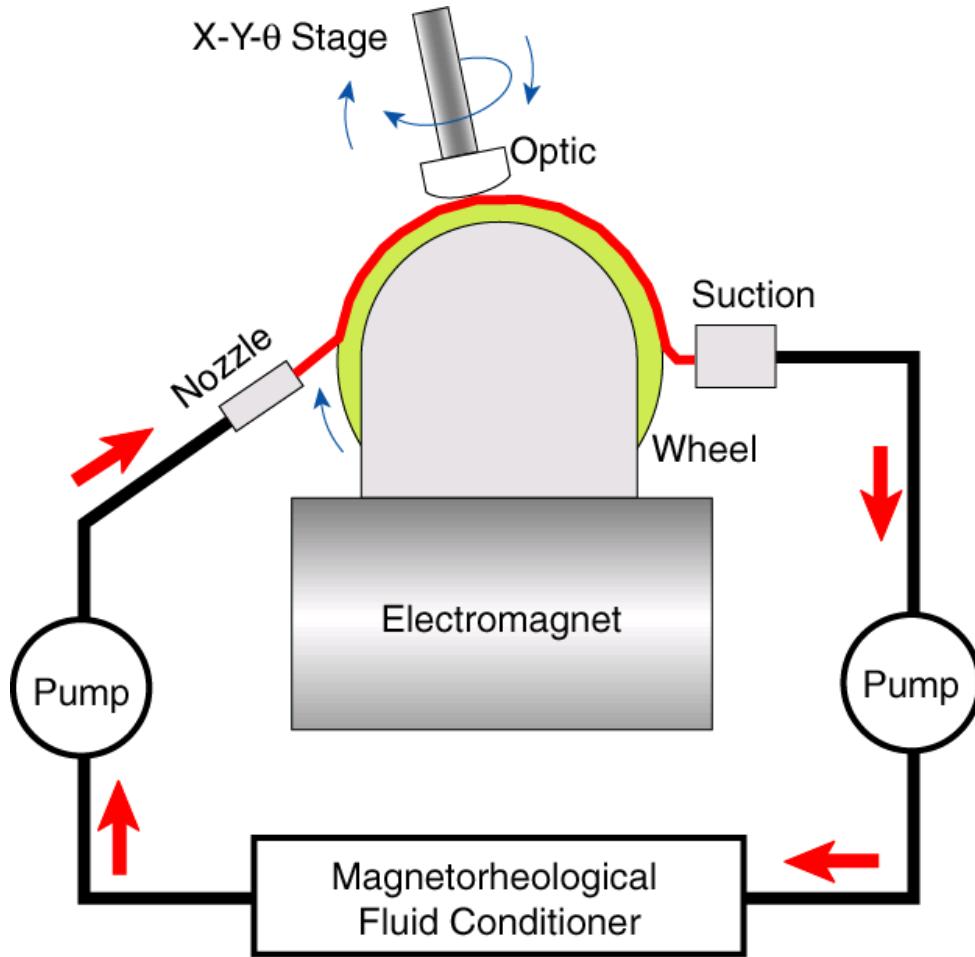
Wolter telescope reflection grating optics



X-ray reflection grating geometry (in-plane diffraction)



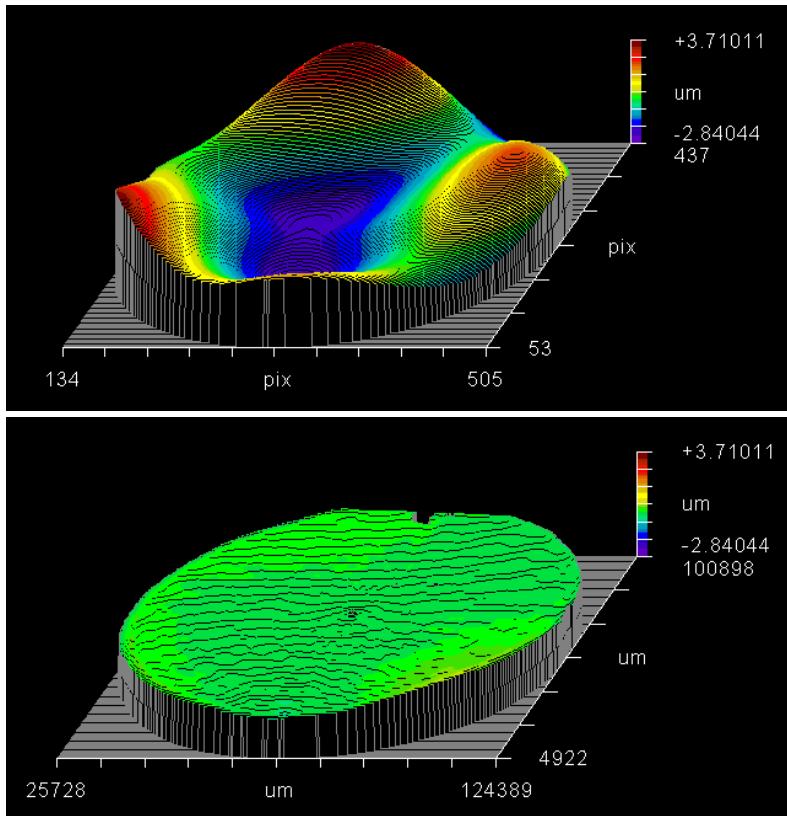
Principle of magneto-rheologic polishing



Wafer polishing results with MRF



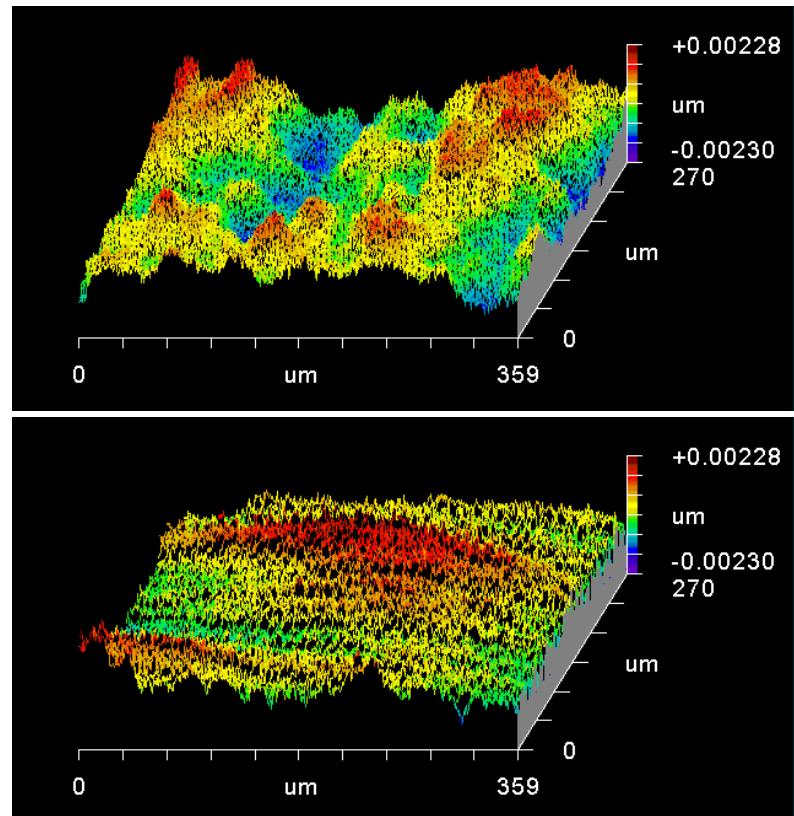
Bow & Warp



Before - 6.55 μm

After - 0.81 μm

rms microroughness



Before – 0.66 nm

After – 0.64 nm

Material:

Silicon

Diameter:

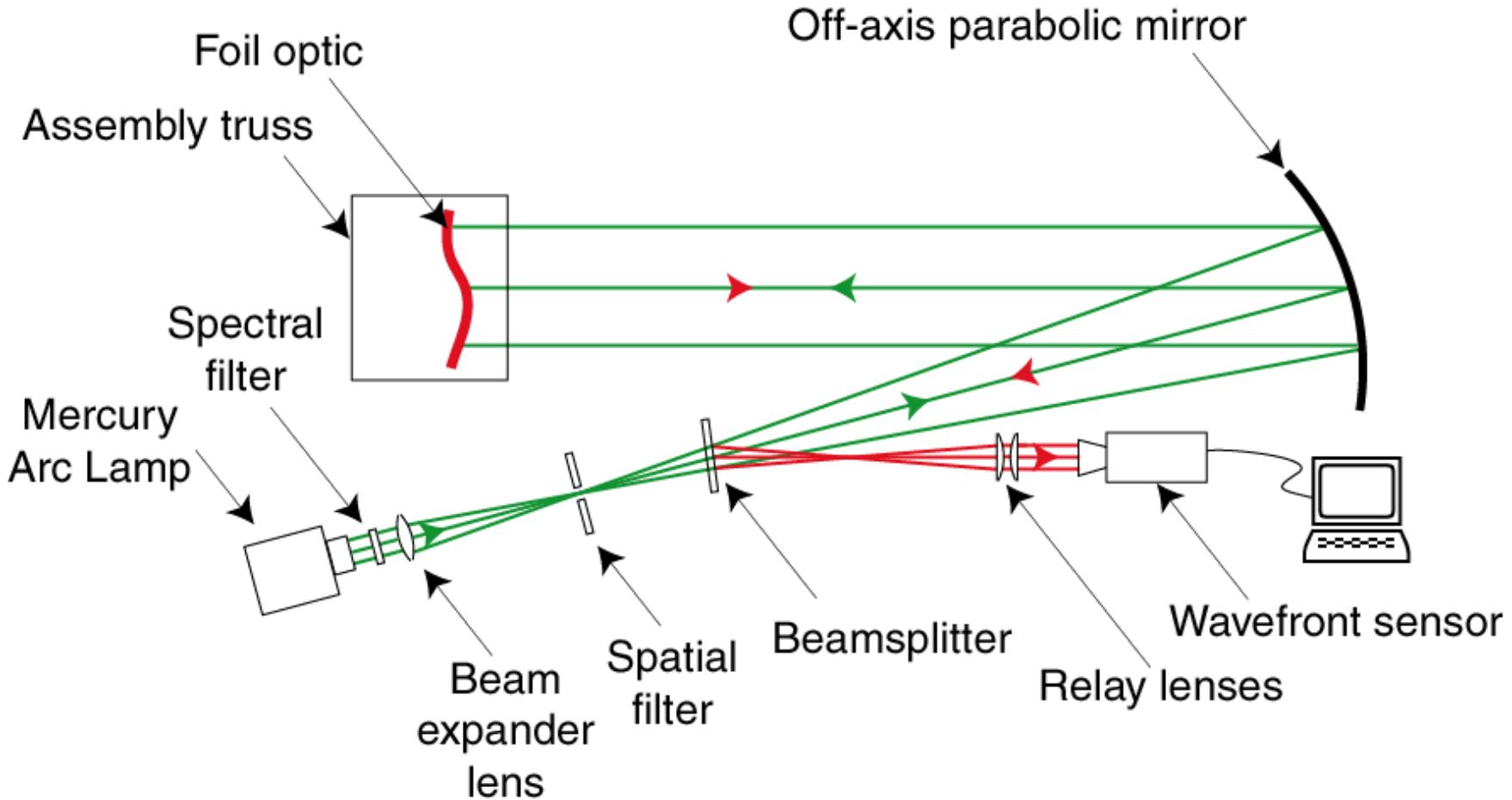
100 mm

Thickness:

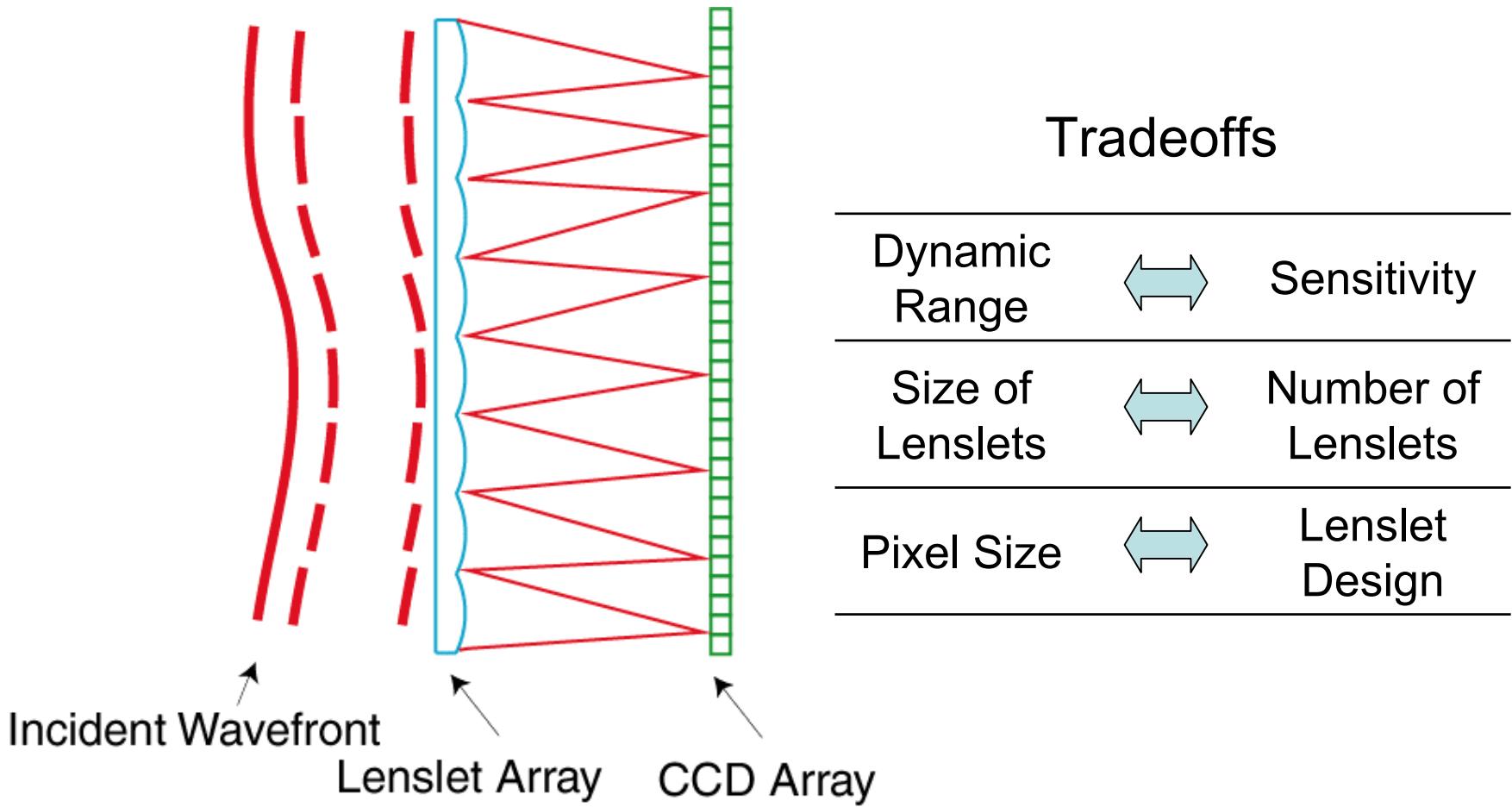
0.45 mm



Shack-Hartmann metrology tool



Shack-Hartmann concept



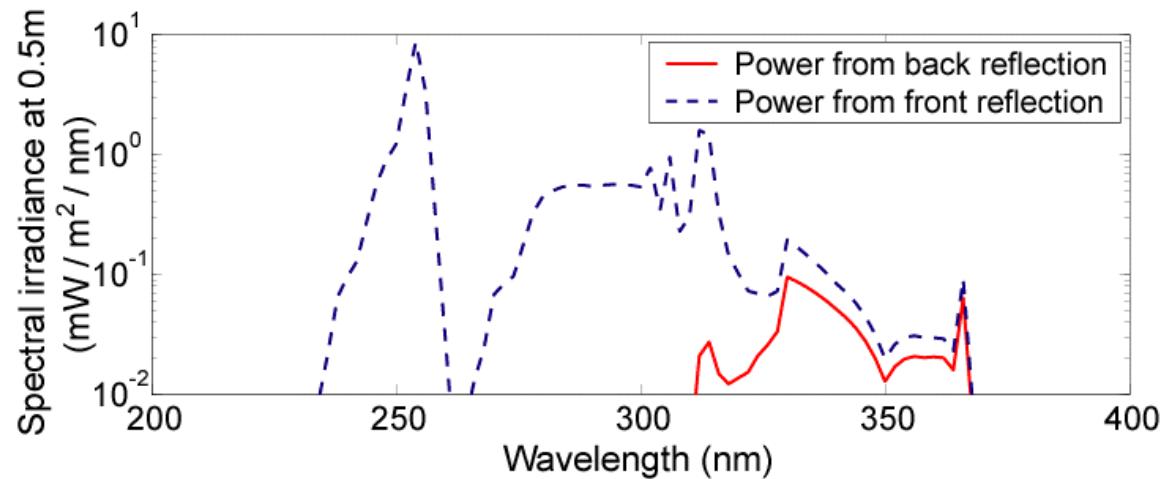
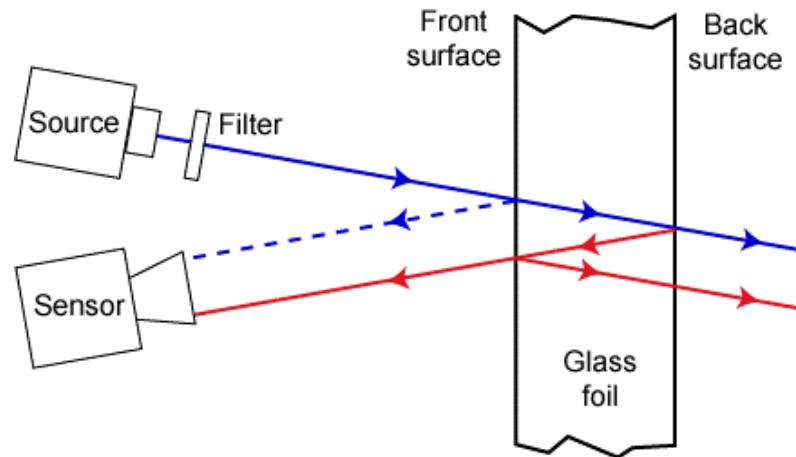
Design considerations

Spectral Filtering

Source
irradiance

Spectral filter
transmittance

Glass optical
properties

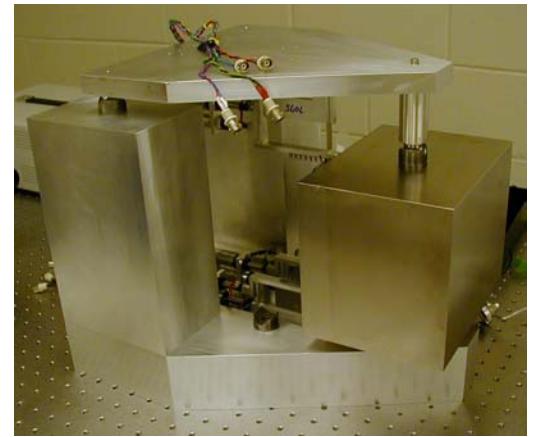
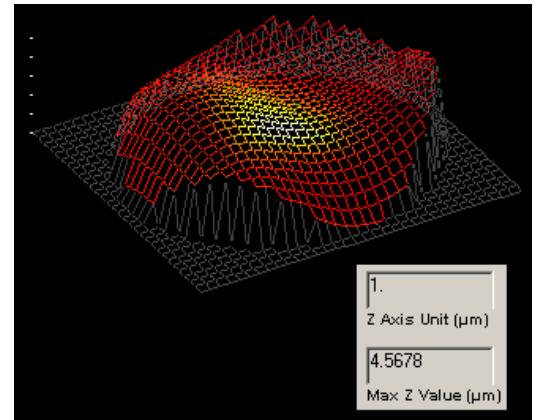
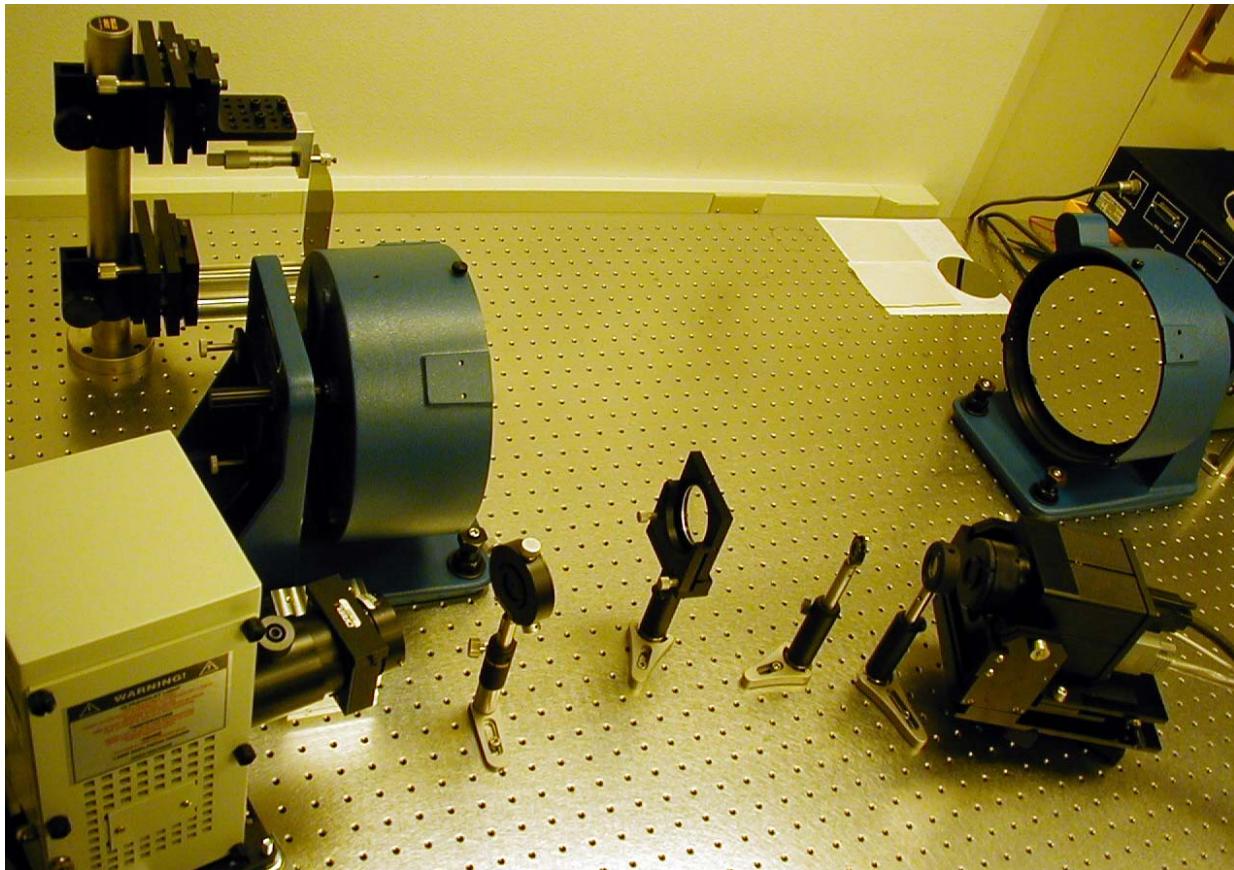


Performance evaluation

Setup	Statistic	P-V (nm)	RMS (nm)
Static Repeated measurements	Range	5.0	0.5
Repeatability Removed and replaced object	Range	35.6	14.0
	Std. Dev.	13.2	5.1
Accuracy Compared two known surfaces	Average	TBD	<16.7

Application

Will meet SNL foil surface metrology needs for >3 years

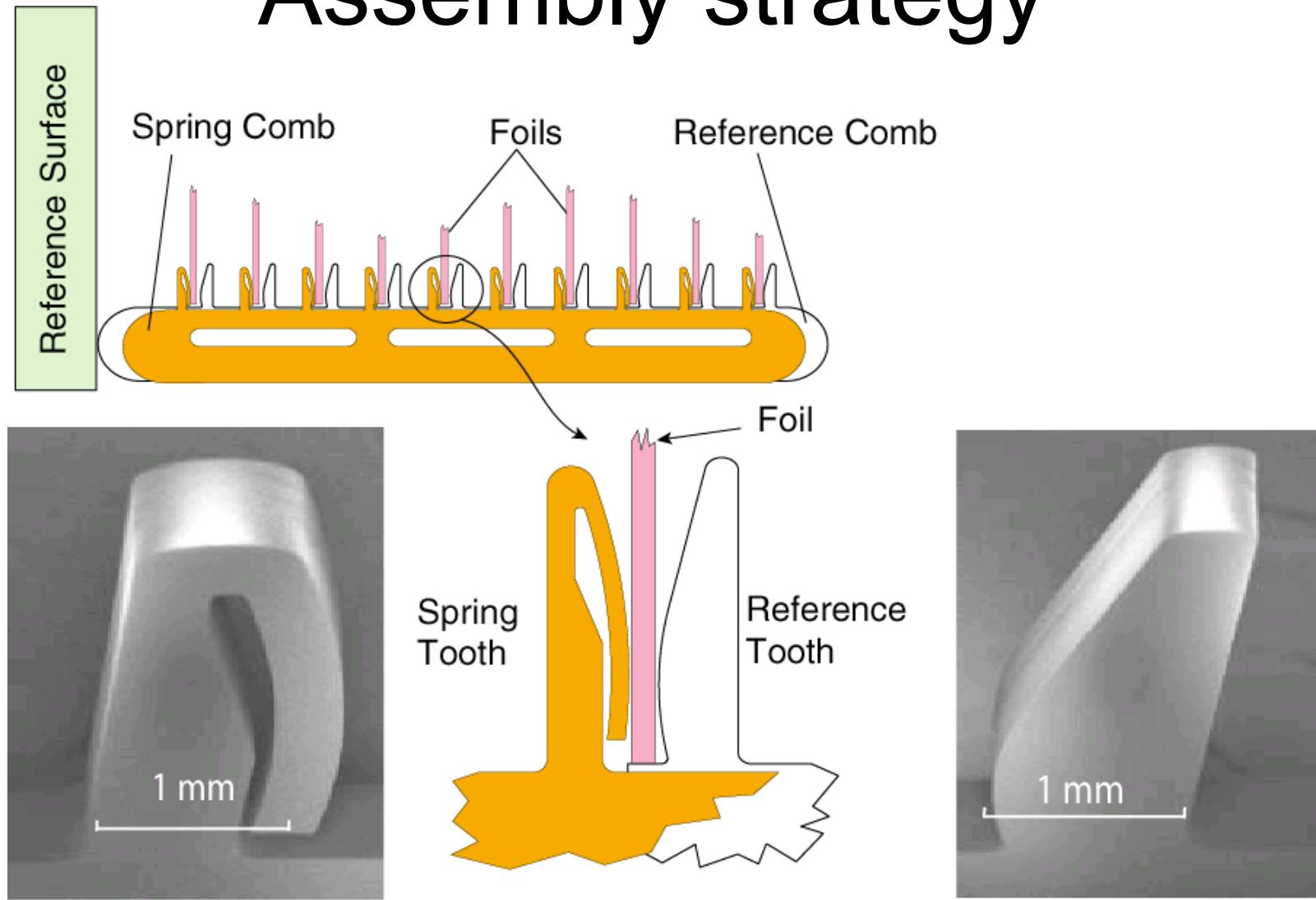


Assembly functional requirements

- Align gratings \parallel to within 1 μm of ideal
 - Repeatably
 - Same grating position between 2 different modules
 - Accurately
 - 2 foil positions within same flight module
- Integrate flight module



Assembly strategy

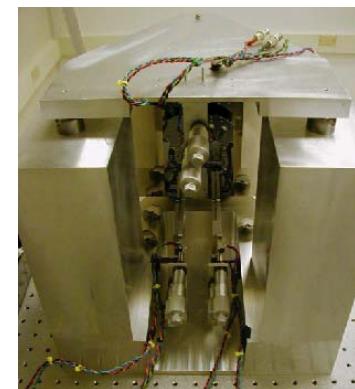
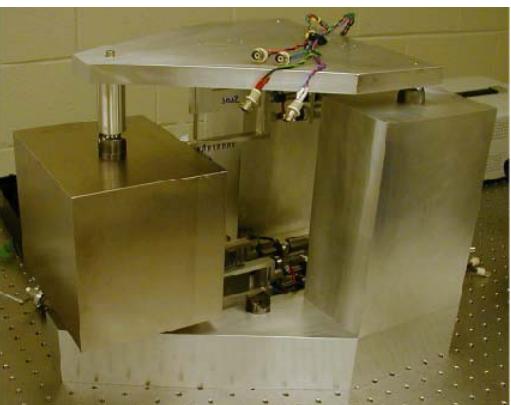
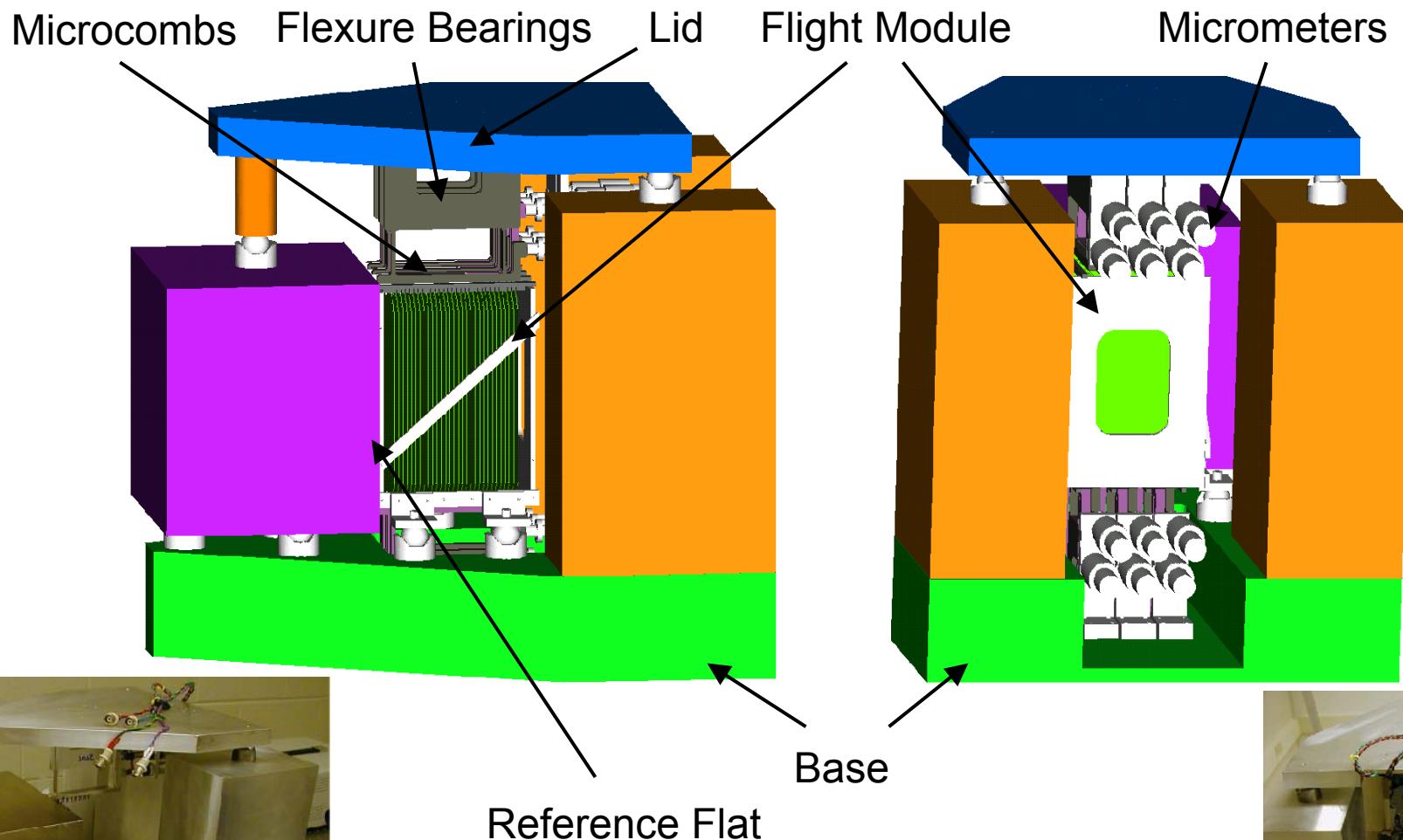


CSR

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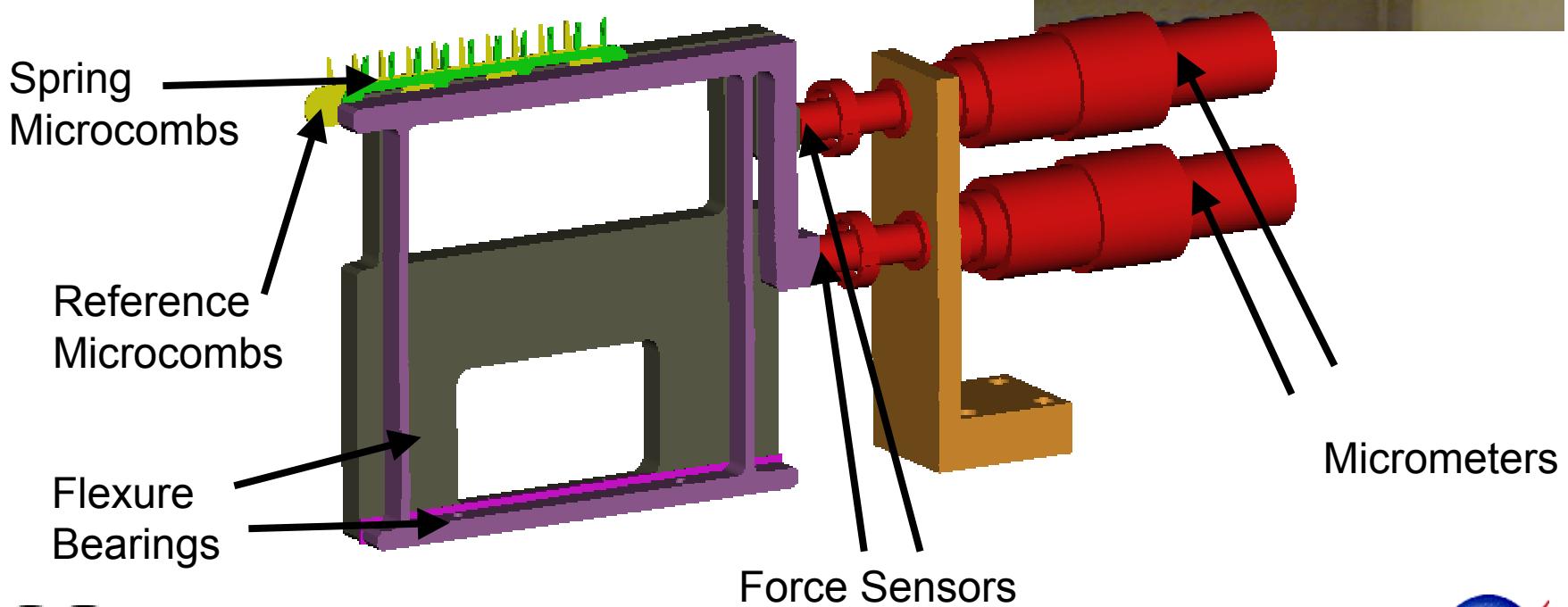


Assembly Truss



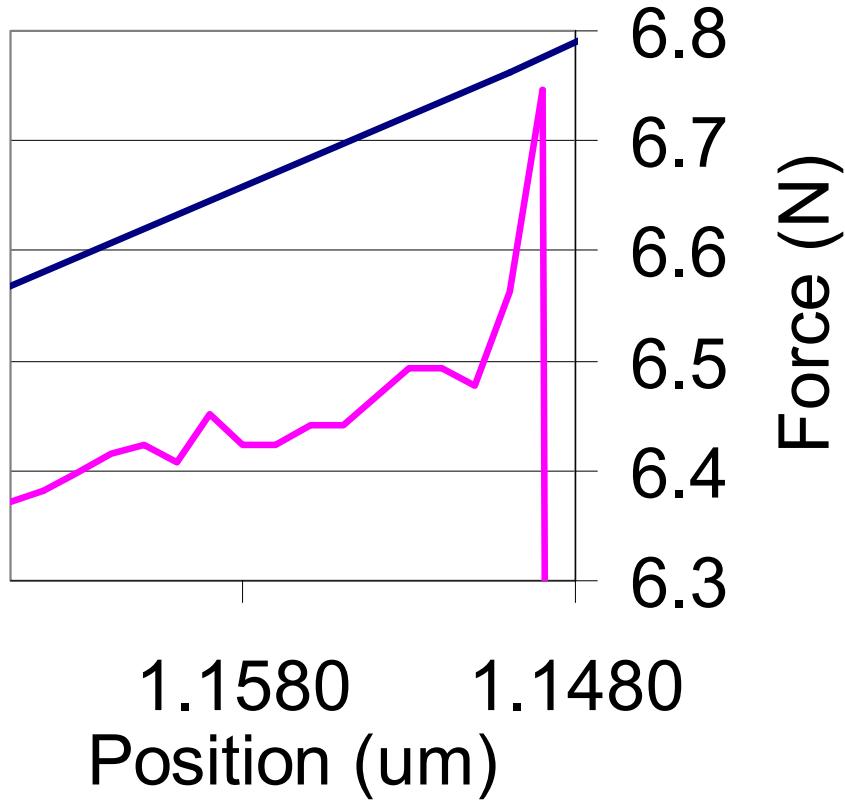
Comb actuation

- Need to move combs until they touch the reference flat
- Hertz contact stresses detectable
- $0.1\mu\text{m}$ actuation capability
- No hysteresis motion



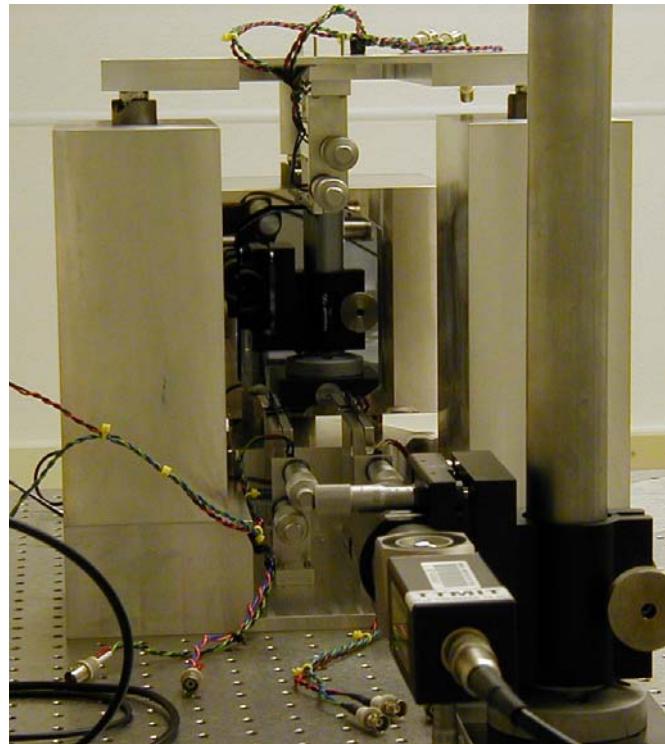
Optic alignment testing

Contact!

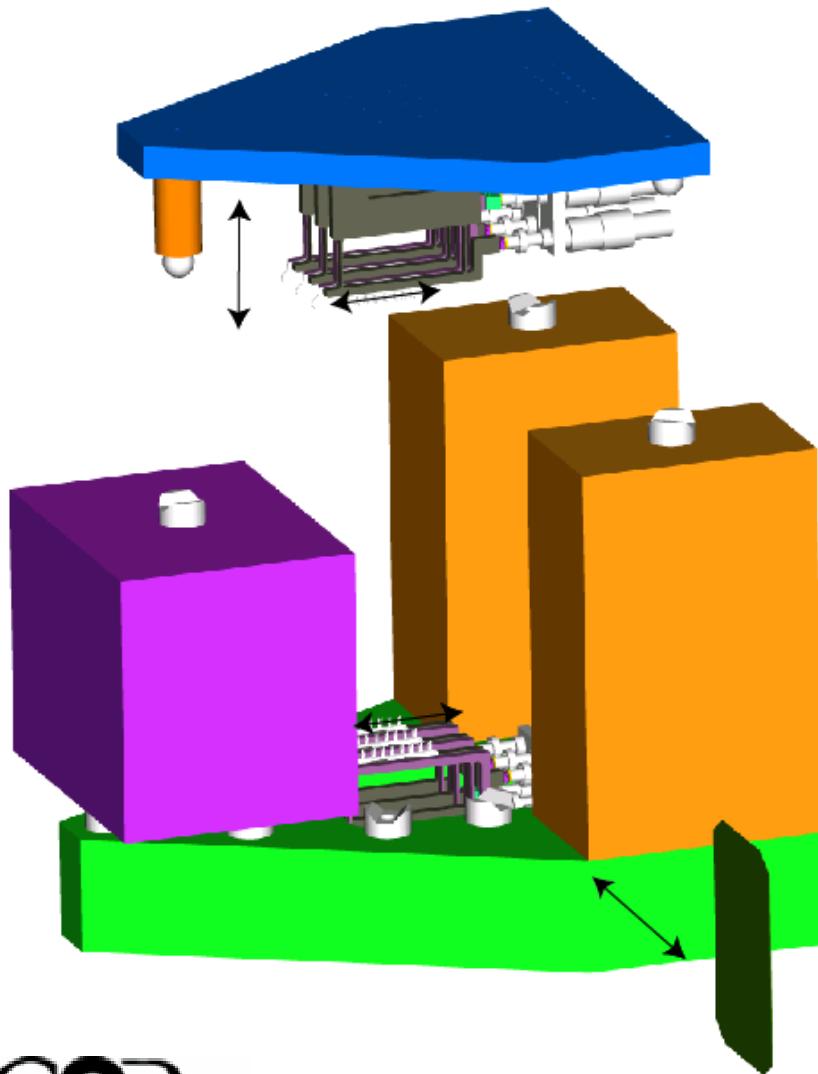


Optic angle measurement

- Autocollimator
- $0.1\mu\text{rad}$ resolution



Precision assembly



Single slot repeatability test
displacement error
one sigma (μm)

0.4mm thick Si wafer	3 mm thick Quartz plate		
Pitch	Yaw	Pitch	Yaw
0.34	0.36	0.33	0.30

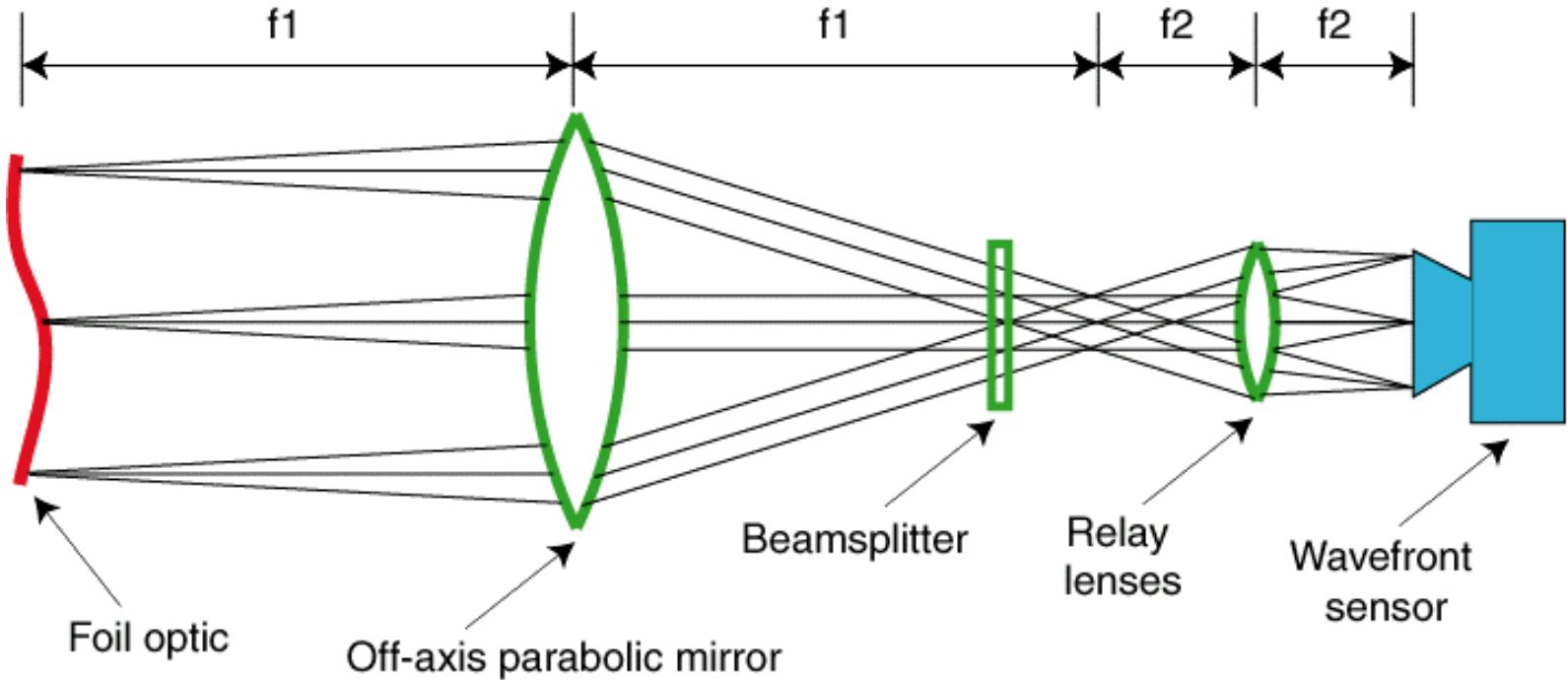
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Keplerian Design



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ L_2 & 1 \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{f_2} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ f_1 + f_2 & 1 \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{f_1} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ L_1 & 1 \end{bmatrix} = \begin{bmatrix} 1/M & 0 \\ 0 & M \end{bmatrix}$$